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# **Lessons Learned From Utilizing PEMs In A Flight/Safety Critical System**

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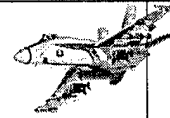
## BACKGROUND



- ◆ In 1997 the Naval Air Systems Command F/A-18 Flight Control Team was tasked with redesigning the Flight Control Computer's processor card.
- ◆ This was mainly due to parts obsolescence.
- ◆ The old processor incorporated mid-80s technology.
- ◆ The processor card contract was awarded to the current computer manufacturer.

Lessons Learned from Utilizing PEMs in a Flight/Critical System

## ISSUES UTILIZING PEMs



### ◆ Issues raised due to the obsolescence of military rated ceramic microcircuits:

- Design options limited using only MIL parts or PEMs with full MIL temp rating
- Microcircuit Industry market is PEMs
- The most common rating for PEMs in the marketplace today is the commercial grade of 0°C to 70°C.
- How to use and qualify commercial grade PEMs for a Military Flight Critical System.

Lessons Learned from Utilizing PEMs in a Flight/Critical System

The issues faced by the F/A-18 Team were on the obsolescence of military rated ceramic microcircuits, industry turning to PEMs, and how to use and qualify commercial grade PEMs for flight critical systems.

PEMs are becoming the standard rating.

## PEMs SELECTION



### ◆ Criteria and Guidelines for Selecting PEMs:

- NAVAIR established "Order of Preference"
  - ◆ QML ceramic microcircuits/PEMs
  - ◆ Military grade PEMs (-55 to 125°C)
  - ◆ Industrial grade PEMs (-25/-40 to 85°C)
  - ◆ Commercial grade PEMs (0 to 70°C)
- Approved Parts Management Program (PMP)
  - ◆ Compliance with Aircraft Contractor's PMP
  - ◆ Compliance with Sub-Contractor's PMP

Lessons Learned from Utilizing PEMs in a Flight/Critical System

A Procurement Spec. Change Notice dictated an order of preference:

Initially, no 0-70 degree PEMs were allowed for flight safety equipment. However, due to part availability and design criteria for the processor, it was revised to include 0-70 degree upscreened PEMs to MIL grade.

Ensure adherence to parts management programs:

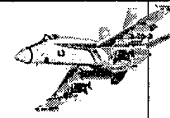
Contractor to review and approve sub-contractor's PMP with agreement to follow contractor's PMP.

Sub-contractor to review and approve supplier's PMP with agreement to follow sub-contractor's PMP.

Both supplier/part selection and part qualification will follow an Approval Process.

The approval will be based on the ability of the plan to meet the objectives and requirements of the program. Including revisions to the plan.

# PARTS MANAGEMENT



## ◆ The Sub-Contractor's Parts Management Program will include the following:

### ■ Supplier/Part Selection Criteria:

- ◆ Process QML certified.
- ◆ Review/approve environmental test data and component quality plan.
- ◆ Evaluate PEM design/fabrication process
- ◆ Conduct a Reliability Analysis

### ■ Minimum Part Qualification Tests:

- ◆ HAST\*: 96hrs @+130°C, 85%RH
- ◆ Steady State Life: MIL-STD-883, TM 1005
- ◆ Temperature Cycling: 1000 cycles, JESD 22-A104, Condition B (-65 to 150°C)

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(several options to qualify): (read slide)

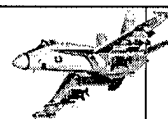
Select preferred processes and materials (e.g., encapsulant, lead frame, die passivation layer, wire bonding, and die thickness). If sufficient data is not available, a qualification test shall be performed in accordance with the processor manufacturer's Parts Plan (this is prior to upscreening).

A reliability assessment of the design incorporating the PEM shall be conducted. This assessment should include: (1) evaluation of the candidate part from all aspects of design, reliability, and quality, (2) performance of an electrical stress analysis using worst-case application stresses and application of any program unique derating guidelines and criteria, (3) preparation of a preliminary reliability prediction to determine if the design will meet the system-level reliability requirements, (4) preparation and evaluation of a Failure Modes, Effects, and Criticality Analysis (FMECA) for the application of PEMs in flight critical applications. The FMECA shall also identify all vehicle or subsystem failure modes which subject PEMs in flight critical systems to exposure to thermal or electrical conditions beyond PEM vendor specifications (after applying any program unique derating guidelines and criteria).

**Minimum Part Qual Tests:** (read slide) PEM qualification involves the data used:

- (1) Qualification by data: (1) data from PEM qualification test conducted by the PEM manufacturer, (2) data from PEM qualification test conducted by third party test house or industrial organization, (3) data from the PEM manufacturer's quality control program, and (4) data from supplier's use of the PEM in similar applications. PEM in-service data may be used in lieu of PEM qualification testing. The sample size should be a minimum of 200 PEMs with more than two years in-service experience per PEM.
- (2) Qualifying by establishing the similarity of a PEM to a qualified PEM: PEMs that share common features (e.g., device technology, package technology, device size, package size, supplier, testing, etc.). The use of data from one PEM manufacturer's products to justify qualification of another manufacturer's products is not acceptable.
- (3) Requalifying a PEM or supplier may be required when the manufacturer makes changes in the package material, size, fabrication process, PEM materials, PEM design, assembly plant, or other relevant factors. The plan should document the types of changes which will require requalification as well as the process for implementation.

## TWO STEPS FOR SAFETY CRITICAL APPLICATIONS



### ◆ Verify the Parts

- Upscreen ALL PEMs to beyond expected worst case equipment operating conditions
- Check against vendor component specifications
  - ◆ But do you test for all relevant parameters to ensure robust circuit function?

### ◆ Verify the End Item

- Subject EVERY manufactured and repaired card or box to worst case equipment thermal environment.
- Catches effects of component parameter variations not in spec sheet or checked in upscreen process

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Part upscreen necessary, but may not catch every parameter important to a specific circuit application.

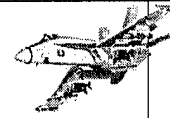
Need to verify end-item operation at worst case thermal environment at least once before delivery.

Reliability degradation (if any) caused by worst case environmental screening is the price to be paid for using PEMS beyond the manufacturers ratings in safety-critical systems. System redundancy mitigates any loss of component reliability. Result is more frequent maintenance actions, not reduced safety.

This path DOES NOT work for safety-critical systems which do not incorporate hardware redundancy.

Application of PEMs in flight critical systems shall avoid compromising the redundancy by introducing common mode failures through simultaneous overstress of hardware in redundant paths.

## UPSCREENING PEMs



- ◆ The processor PEMs required upscreening to the military grade rating due to the use of commercial grade PEMs (0°C to 70°C).
- ◆ Upscreening will be performed on 100% of the PEMs; including the industrial grade PEMs.
- ◆ An outside testing facility conducts the PEMs upscreening.
- ◆ Electrical characterization is performed to ensure performance specification is within limits.
- ◆ Part qualifies for Application Environment.

Lessons Learned from Utilizing PEMs in a Flight/Critical System

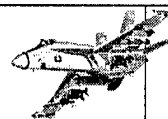
### Application Environment:

For the proper application of PEMs in military equipment, the application environment needs to be defined and analyzed. The application environment assessment will include the: (1) specific operating and non-operating environment the unit will experience, (2) environmental extremes for temperature, vibration, humidity, salt atmosphere, and shock, and (3) frequency of these stresses.

The operational profile will be used to support the definition of the part functional requirements. This will include: (1) defining the frequency of the power application, (2) the variations in the input voltage/current and the output loading, (3) the temperature and humidity extremes during the power-on cycle, and (4) the duration of the power application.

Structural/thermal design and analysis include: (1) the assessment of the mechanical interfaces of the electronics to the chassis and the chassis to the system, (2) the structural rigidity of the electronics boards, (3) possible thermal paths, (4) the mounting technique for the electronic parts (e.g. surface mount versus thru-hole), (5) the accessibility to the electronics, and (6) electronic component mounting integrity under the combined effects of differential thermal expansion and vibration.

## **ENVIRONMENTAL STRESS SCREENING**

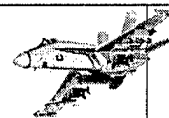


◆ **Conducting ESS at the card and/or box level to the worst case operational environment (On every card and/or box).**

- Realistic operating conditions established.
- Emergency flight conditions accounted for.
- Thermal survey conducted to extreme conditions.
- Qualification and ESS test profile developed to test system at normal and emergency conditions.

Lessons Learned from Utilizing PEMs in a Flight/Critical System

## EXPERIENCE



◆ During design verification a critical issue was discovered (upscreening):

- Loss of Dynamic RAM (DRAM) data at high temperature ( $> 100^{\circ}\text{C}$  case).
- DRAM required faster (than spec sheet) refresh rate at high temperature.
- DRAM refresh controller could not be programmed for faster refresh, and was part of a complex "glue" chip.
- Major redesign required to correct the problem.

Lessons Learned from Utilizing PEMs in a Flight/Critical System

## LESSONS LEARNED



- ◆ **Ensure you have a sound and complete Parts Management Program that flows down to sub-contractors and component manufacturers. Ensure that it's reviewed, updated, and complied with.**
- ◆ **When upscreening, factor risk into your program:**
  - **Schedule increases (redesigns, low yield rates, test house).**
  - **Cost increases (test house upscreening, short life cycle).**
- ◆ **The most important for flight critical systems: Conduct a thermal survey of your system at the worst case environment and perform qualification testing, at the box level, up to that environment.**
- ◆ **Test every manufactured and repaired system to the expected worst case thermal environment.**

Lessons Learned from Utilizing PEMS in a Flight/Critical System